विश्वेश्वरानन्द-संस्थान-प्रकाशनम् —५१६

विश्वेश्वरानन्द-भारतभारती-ग्रन्थमाला-४७

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नीलकण्ठसोमयाजि-विरचितः

गोलसारः

GOLASĀRA

OF

GĀRGYA-KERALA

NĪLAKAṆṬHA SOMAYĀJI

Critically Edited with Introduction

By

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होशिआरपुरम्

HOSHIARPUR

विश्वेश्वरानन्द-संस्थानम्

VISHVESHVARANAND INSTITUTE

1970

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INTRODUCTION

Tradition of Astronomy in Kerala

The *Golasāra* presented here in a critical edition is an important minor work of Nīlakaṇṭha Somayāji, a noted astronomer of Kerala of the 15th-16th centuries. The Kerala region has a long tradition of astronomical studies, both at the empirical and experimental levels —a tradition which continued till the last century—under the enlightened patronage of local dignitaries and unhampered by alien or other invasions which disrupted such studies in several other parts of India. Many an innovation and discovery in mathematics and astronomy has been ascribed to scholars from this region.[1] Among the more important astronomers of the later period may be mentioned, Govinda Bhaṭṭatiri (A. D. 1237-95), Mādhava of Saṅgamagrāma (*c.* 1340-1425), Parameśvara of Vaṭaśśeri (1360-1455), Citrabhānu (*c.* 1475-1550), Śaṅkara Vāriyar of Tṛkkuṭaveli (*c.* 1500-60), Śaṅkaran Nampūtiri of Mahiṣamaṅgalam (1494-1570), Jyeṣṭhadeva (1500-1600), Acyuta Piṣāraṭi (*c.* 1550-1621), Putumana Somayāji (*c.* 1700-60) and Śaṅkaravarman of Kaṭattanāḍ (1800-38). Nīlakaṇṭha Somayāji, our author, belongs to this distinguished galaxy of astronomers and besides being the author of several texts on astronomy, is also a practical astronomer.

Golasāra

The *Golasāra* is a short work in 56 *āryā* verses, divided into three *paricchedas*, containing, respectively, 11, 15 and 30 verses. The first *pariccheda* sets out the basic astronomical constants, *viz.*, the number of civil days and the revolutions of the planets in an aeon, the positions of the higher apses and the ascending nodes of the planets, their maximum latitudes, their epicycles to the equations of the apses

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1. On Kerala mathematicians and astronomers, see : K. Sankara Menon, *Indian astronomy with special reference to the works of Kerala authors*, (Ph. D. Thesis, Madras University, 1927), T. A. Sarasvati, *Geometry in ancient and medieval India*, (Ph. D. Thesis, Madras University, 1964), and K. Kunjunni Raja, 'Astronomy and mathematics in Kerala (An account of the literature)', *Adyar Library Bulletin*, 28 (1963) 118-67.

and of conjunction, the diameters of the orbits of the sun and the moon and the *yojana* measures of the epicycles.

Pariccheda II is concerned with the presentation of the celestial globe (*Jyotirgola*) from the point of view of astronomical conceptions and observations and the movement, therein, of the heavenly bodies. The position of the great circles, *Ghaṭikā-maṇḍala* (celestial equator) and the *Apakrama-maṇḍala* (ecliptic), their mutual obliquity, the division of the ecliptic, the (apparent) rotation of the celestial globe, the rising point of the ecliptic (*lagna*), the measure of the orbits of the planets, the measurement of the positions of the planets on the ecliptic and the position of the horizon (*Unmaṇḍala*) at the equator and elsewhere are noticed here, in order.

In *Pariccheda* III, verses 1 to 15 deal with the circle and the graphical and computational derivation of the Sines. Verses 16 to 30 discuss the inter-relationship of the *Manda*, *Śīghra* and *Kakṣyā* circles of the different planets and also how the results arrived at by calculation of the positions of the planets are affected by their *kṣepa* (deflection) from the ecliptic.

Manuscript Material

The present edition of *Golasāra* is based on seven mutually independent palmleaf manuscripts, designated **A** to **G**, all originating from the Kerala region and written in the local script, *viz.*, Malayalam. These seven manuscripts, however, sort themselves out into three distinct groups, group I being composed of Mss. **A** to **C**, Group II, of Mss. **D** and **E**, and Group III, of Mss. **F** and **G**.

Group I

A : Ms. No. C 1024-E of the Curator's Office collection of the Kerala University Oriental Res. Inst. and Mss. Library, Trivandrum, described in the *Des. Cata. of Skt. Mss. of the Curator's Office Library*, Vol. IV, pp. 1319-21, under Ser. No. 633-E. *Golasāra* is contained in the first few leaves of the manuscript, the rest being occupied by other miscellaneous matter ; possibly, on account of this, the Catalogue describes the work as incomplete. The Ms. belonged originally to the family collection of the Raja of Chirakkal in N. Kerala. There is also a transcript of this Ms. in the Library, No. T 846-B. The text contained is complete and fairly accurate. The textual verses are found arranged herein exactly as printed in the present edition, *viz.*, in the *paricchedas* of 11, 15 and 30 verses, respectively.

The Ms. exhibits few scribal or other errors. The codex contains also other astronomical works, among which is another work of Nīlakaṇṭha, *viz.*, the *Siddhāntadarpaṇa*, numbered as C 1024-F.

B : Ms. No. 8358-E of the University collection of the above Library. The text contained is complete and generally correct. The arrangement of the verses follows that in **A**.

C : Catalogue No. 6301 of the India Office Library, London, described in the *Cata. of the Skt. and Pkt. Mss. of the India Office*, Vol. II, (Oxford, 1935), pp. 774-75. The collation was done on the basis of a microfilm copy of the Ms. supplied by the India Office. The text preserved herein is generally pure and the writing free from mistakes though the description in the *Catalogue* asserts that "the Ms. is very far from accurate". There is some astronomical matter written in continuation, which, too, the cataloguer has taken as part of the present work. The arrangement of the verses is as in **A** and **B**. The work written next in the codex is the *Siddhāntadarpaṇa* of Nīlakaṇṭha. One page of the manuscript has been left out from being photographed while microfilming the manuscript and hence the portion contained therein, being I.8d and to a portion of II.4d, could not be collated.

Group II

D : Ms. No, 1869-C of the Curator's Office collection of the Kerala University Mss. Library, described in the *Catalogue*, (*ibid*), p. 1343, as Ser. No. 636-B. The Ms. had been procured from Shri Brahmadattan Nampūtiri, Kudalur (S. Malabar). The text is incomplete, going only up to III. 24. Nīlakaṇṭha's *Siddhāntadarpaṇa* is found in continuation in the manuscript. The ms. takes I. 1-11 and II. 1-9 as *Pariccheda* I and II. 10-15 as *Pariccheda* II, the colophons reading accordingly ; *Pariccheda* III remains as it is.

E : A manuscript belonging to Shri Rama Varma Maru Thampuran, Chalakkudi (Cochin). The Ms. is generally correct, but breakes off with III. 24, even as D. does, but one is not a direct copy of the other as attested by minor differences in their readings. The verses are arranged as in D.

Group III

F : Ms. No. 5867-B of the University collection of the Kerala University Mss. Library. The Ms. is well preserved and generally

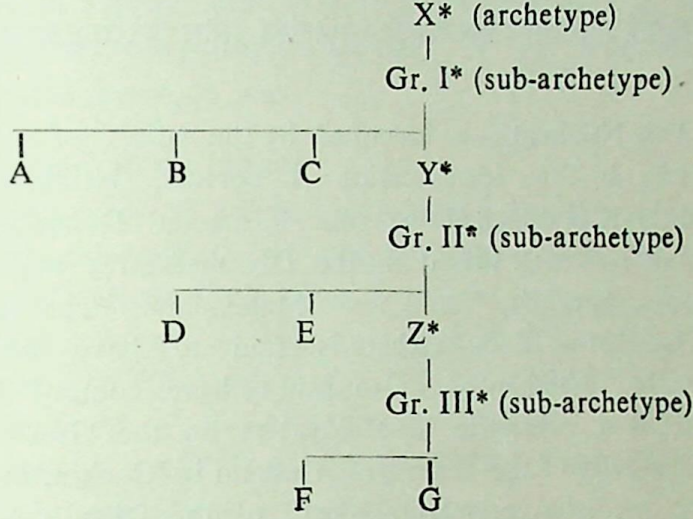
accurate. It omits the first *Pariccheda* entirely, designates verses II. 1-9 as *Pariccheda* I, and II.10 and 15 as *Pariccheda* II, the Third *Pariccheda* being as it is in other manuscripts.

G : Ms. No. R 5151 (a) of the Government Oriental Mss. Library, Madras, described in their *Triennial Cata. of Skt. Mss.*, Vol VI, pp. 7068-69. This is a paper transcript in Grantha characters, copied in 1925-26. from a palmleaf Ms. in Malayalam script belonging to Shri Tuppan Nampūtirippāḍ, Ponnorkottu Mana, Perumbavoor (Kerala). Like Ms. F, here too, *Pariccheda* I is dropped and *Pariccheda* II divided and designated as I and II. The text preserved herein contains a large number of corrupt readings, either because the original Ms. was erratic or the modern scribe did not decipher the writing properly. Obvious errors and wrong decipherments have been ignored in the matter of giving variants in the edition hereinbelow.

Versions of Golasāra

It would be seen from the above that the manuscripts of *Golasāra* resolve themselves into three distinct groups, on the basis of the distribution of verses in the three *paricchedas*, being I : 11, 15, 30 ; II: 20, 6, 30 ; and III: 9, 6, 30. This grouping is corroborated also by the variant readings presented by the manuscripts. From the point of view of contents, the first division, according to which the first *pariccheda* presents the fundamental astronomical constants, the second sets out the situation of the celestial globe and of the planets therein, and the third explains the calculation of the position of the celestial bodies, is the most natural, besides being logical and compact. A mathematician of the stature of Nilakaṇṭha cannot be expected to arrange his work otherwise. This version of *Golasāra*, represented by three of the available manuscripts **A**, **B** and **C**, has, therefore, been taken as the basic version in the edition of the text presented here.

It is possible to posit the derivation of Groups II and III from Group I, by manuscript corruption, which should have occurred in two stages : (1) In an exemplar, the colophon of *Pariccheda* I should have been inscribed by the revisor of the manuscript, at the bottom of the leaf (where II. 9 had ended), with due indication of its correct place ; when, however, a copy was prepared from that exemplar, the revisor's indication was unnoticed and the colophon, which was written at the bottom, instead of being inserted properly after I. 11, got attached to II. 9, resulting in the archetype of the Group II manuscripts. Our manuscripts **D** and **E** should have descended from a manuscript of this derivation.

Group III manuscripts, *viz.*, **F** and **G**, should have descended from a Group II exemplar in which the first eleven verses were missing. The above-said possible derivation might be represented by the following *stemma codicum* :

The Author

Nīlakaṇṭha is generally referred to with the title *Somayājin*, *Somasut*, *Somasutvan* or *Comātiri*. A detailed colophon occurring at the end of his *Bhāṣya* on the *Gaṇitapāda* of the *Āryabhaṭīya*, contains a good deal of useful information about him : इति श्री-कुण्डग्रामजेन गार्ग्यगोत्रेण आश्वलायनेन भाट्टेन केरलसद्ग्राम-गृहस्थेन श्री-श्वेतारण्यनाथ-परमेश्वर-करुणाधिकरणभूत-विग्रहेण जातवेदःपुत्रेण शङ्कराग्रजेन जातवेदोमातुलेन दृग्गणितनिर्मापक-परमेश्वर-पुत्र-श्री-दामोदरात्तज्योतिषामयनेन रवित आत्तवेदान्तशास्त्रेण सुब्रह्मण्यसहृदयेन नीलकण्ठेन सोमसुता विरचितविविधग्रन्थेन दृष्टबहूपपत्तिना स्थापितपरमार्थेन कालेन शङ्कराद्य (? य) निर्मिते श्रीमदार्यभटसिद्धान्त-व्याख्याने महाभाष्ये etc.[1]

Personal Details

Thus, Nīlakaṇṭha belonged to the Gārgya gotra, was a follower of the *Āśvalāyana-sūtra* of the *Ṛgveda* and was a *Bhāṭṭa*. He was the son of Jātavedas and had a younger brother named Śaṅkara. He had an uncle Jātavedas by name and a close friend Subrahmaṇya. He was a performer of the *Soma* sacrifice. He had composed several works on Astronomy, in which subject he had made deep and extensive investigations, a fact which is well borne out by his available works.

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1. Ed., *Trivandrum Sanskrit Series*, (*TSS*), No. 101, (Trivandrum, 1930), p. 180.

Some more personal details about Nīlakaṇṭha seem to be forthcoming from a Malayalam work *Laghurāmāyaṇa*.[1] This work describes itself as a work of Rāma, son of Nīlakaṇṭha of Gāryga gotra and resident of Kuṇḍagrāma; *cf.* the colophon at its end : इति कुण्डग्रामजेन गार्ग्यकुलतिलकेन श्री-नीलकण्ठात्मजेन आर्याम्बा-गर्भसम्भवेन मन्वादिस्मृतिमर्मज्ञ-संस्कृत-द्राविडभाषाद्वयपारीणस्य दक्षिणामूर्तिनाम्नोग्रजेन रामेण विरचितं श्रीरामायणम् प्रबन्धम् ।

This Nīlakaṇṭha is identified by the editor of the work with our author.[2] If this identification is correct, Nīlakaṇṭha's wife was named Āryā, and he had two sons Rāma and Dakṣiṇāmūrti, the latter of whom was well versed in the Dharmaśāstras and learned in three languages, Sanskrit, Tamil and Malayalam. The great Malayalam poet Tunchattu Ezhuttacchan is said to have been a student of Nīlakaṇṭha. Nīlakaṇṭha is also said to have composed at the request of a friend a panegyric in Malayalam on the Goddess Pārvatī, the presiding deity of the temple of Ūrakam in Cochin, in order to ward off the predicted premature death of the friend's daughter.[3] The authenticity of the above work and the source of the information are, however, not quite certain, and, so, corroborative evidences have to be found before accepting the above statements.

Birthplace and House

Nīlakaṇṭha hailed from Tṛ-k-kaṇṭiyūr (Sanskritised into Kuṇḍapura or Kuṇḍagrāma), near Tirur, S.Ry., Ponani taluk, South Malabar, a famous seat of learning in Kerala during the middle ages. The name of his *Illam*,—as the house of a Nampūtiri Brāhman is called,-was Keḷallūr (sometimes spelt also as Kerallūr). It is Sanskritised into Kerala-sad-grāma corresponding to the Malayalam word Keraḷa-nal-l-ūr.[4] Nīlakaṇṭha's house is identified with the present Eṭamana

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1. Ed. P.R. Menon, *Tunchattu Granthāvali*, No. 3, Tunchattu Karyalayam, Chittoor, 2nd edn., 1939.

2. *Vide* P.R. Menon, his article 'Tunchattu Ezhuttacchan', in the Malayalam monthly *Tunchattu Ezhuttacchan*, 3 (1952-53) 127-35.

3. *Ibid.* This stotra is published in a collection of stotras in Malayalam script, *Stavaratnamālā*, Pt. I.

4. It may be noted that in the expression *Gārgya-Kerala* prefixed to the author's name, the word *Kerala* refers to the name of his house and not to his country, as is sometimes taken.

Illam, situated a little to the south of the local temple.[1] It is stated that Nilakaṇṭha's family became extinct and the family property was inherited by the nearest *dāyadi* relations, viz., the Eṭamana family.[2]

Nilakaṇṭha's favourite deity was Lord Śiva installed at the famous temple at Tṛpparaṅṅoḍ (Sanskrit Śvetāraṇya) near his village; *cf.* श्री-श्वेतारण्यनाथ-परमेश्वर-करुणाधिकरणभूतविग्रहेण, in the colophon to the *Ā. Bhāṣya* quoted above, (p. xi).

Śaṅkara, Brother of the Author

Nilakaṇṭha refers to his younger brother Śaṅkara in several places in the *Ā. Bhāṣya*. Śaṅkara too seems to have been well versed in astronomy and followed his elder brother's studies. Thus, after describing some methods on the Rule of three (*Trairāśika*) in his *Ā. Bhāṣya, Gaṇita.* 26, Nilakaṇṭha says how his brother who was giving tuitions at the house of his patron explained to the latter some of those principles ; *cf.* अत्र केषांचिद् युक्तयः पुनः अस्मदनुजेन शङ्कराख्येन तत्समीपे अध्यापयता वर्तमानेन तस्मै प्रतिपादिताः । (*TSS* 101, p. 156).

Nilakaṇṭha observes at the close of his *Bhāṣya* on the *Golapāda* that he was entrusting the *Bhāṣya* to Śaṅkara for its proper propagation. Thus, just before the final colophon, he says : एवमिदम् अस्माभिर्यथामति व्याख्यातम् ।

नमो भगवते तस्मै श्रीमदार्यभटाय च ।
नमः स्वयम्भुवे तस्मै यत्प्रसादादिदं कृतम् ॥
यदि स न्यायाल्लिप्सेदस्मै दातव्यमेव शङ्कर ते ।
शिष्यं तत्त्वेन विचार्यार्यभटसूत्रभाष्यमिदम् ॥

इति गोलपादव्याख्यानं समाप्तम् ॥

This statement helps also to explain and emend the obscure passage शङ्कराद्यनिर्मिते in the detailed colophon to the work quoted above. Since the *Bhāṣya* was written for his brother Śaṅkara the passage may be read as शङ्कराय निर्मिते ।[3]

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1. *Cf.*, Vatakkumkur Rajaraja Varma, *History of Skt. Lit. in Kerala*, vol. I, (Trivandrum, 1938), p. 334.

2. I am thankful for this information to Sri Rama Varma Maru Thampuran, Chalakkudi (Cochin).

3. *Cf.*. *TSS* 101, p. 180. A variant reading given in the edition as footnote,

Netranārāyaṇa, Patron of Nīlakaṇṭha

That Nīlakaṇṭha was intimately connected to and was patronised by Kauṣītaki Āḍhya Netranārāyaṇa, known locally as Āzhvāñceri Tamprākkal, the religious head of the Nampūtiri Brāhmans of Kerala, is known from several references found in his writings. It is also clear that the patron had great esteem for Nīlakaṇṭha's erudition in astronomy, in which subject he too was interested and used to discuss intricate points with Nīlakaṇṭha. Thus, in the discussion on the calculation of the geocentric motion of planets (*Ārya.*, *Kāla*. 22-25), Nīlakaṇṭha says :[1]

कर्णभुक्तिः स्फुटेत्यत्र व्याख्याने पारमेश्वरे ।
व्यासार्धाप्तं कोटिवर्गात् कर्ण्येणादावृणं धनम् ॥

कोट्यां तदूनयुग् व्यासदलं गतिविधौ श्रुतिः ।
प्रकारान्तरमाहैवं सूक्ष्मभुक्तिप्रसिद्धये ॥

गुरूणां मे पितात्रापि स्थौल्यान्मत्सरिणोदिते ।
परमेश्वर-तच्छिष्या नैव वेलागतिं विदुः ॥

इति कौषीतकी श्रुत्वा नेत्रनारायणः प्रभुः ।
मह्यं न्यवेदयत् तस्मै तदेवं प्रत्यपादयम् ॥

Again, in the long discussion on the calculation of the apparent position of celestial bodies (*Ārya.*, *Kāla*. 17-21), speaking on a method to derive the *sakṛt-karṇa*, our author says :[2] अन्यदपि कर्म अस्माभिरुपन्यस्यमानं श्रुत्वा आढ्येन कौषीतकिना अनुष्टुभा निबद्धम् :

स्वोच्चोनमध्यमार्कस्य भुजाज्याघ्ना त्रिजीविका ।
स्वोच्चहीनस्फुटार्कस्य दोर्ज्याभुक्ता श्रुतिर्भवेत् ॥ इति ॥

This would indicate the intimacy that existed between Nīlakaṇṭha and his patron and the common interest that bound them together. On the compilation of the *Ā. Bhāṣya*, Nīlakaṇṭha observes in one place :

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viz., शंकरार्यनिर्मिते makes no sense. It may also be noted that Ulloor (*Kerala Sāhitya Caritram*, vol. II, Trivandrum, 1954, p. 118) takes it to read शंकरार्यनिमिते, which is not correct.

1. *TSS* 110, p. 63.
2. *Ibid.*, 47.

यन्मयात्र केषांचित् सूत्राणां तद्युक्तीः प्रतिपाद्य कौषीतकिना आढ्येन नारायणाख्येन व्याख्यानं कारितम्, अतस्तदेव अत्र लिख्यते । (*TSS* 101, p. 113). Again, at another context he remarks : इतीदं प्रथमे वयस्येव वर्तमानेन मया द्वितीयवयसि स्थितेन कौषीतकिना आढ्येन कारितम् । ···तस्मिन् स्वर्गते पुनः··· व्याख्यानमारब्धम् । (*TSS* 101, p. 156).

It is clear from this that the credit of enthusing Nīlakaṇṭha in his investigations, and, in fact, to have prompted him to write his *Bhāṣya*, goes to Netranārāyaṇa,[1] the members of whose family are known all through the annals of Kerala history to have been good scholars and at the same time munificent patrons of scholarship.

Nīlakaṇṭha's Teachers : 1. Ravi

Nīlakaṇṭha informs us in his *Bhāṣya* that he studied Vedānta under Ravi, *cf. Ravita ātta-vedāntaśāstreṇa*.[2] That Ravi was well versed also in Jyotiśśāstra and that Nīlakaṇṭha imbibed some of his knowledge in astronomy from him is clear from the introductory verse to Nīlakaṇṭha's *Siddhāntadarpaṇa*, where Ravi, his teacher, has been mentioned by *double entendre* :

श्रीमद्दामोदरं नत्वा भगवन्तं रविं तथा ।
यत्प्रसादान्मया लब्धं ज्योतिश्चरितमुच्यते ॥

A work on astrology entitled *Ācāradīpikā*, being a detailed commentary, in verse, on *Muhūrtāṣṭaka* is ascribed to this Ravi.[3]

2. Dāmodra

The regular teacher of Nīlakaṇṭha who initiated him into the science of astronomy and instructed him on the various principles uuderlying mathematical calculations was Dāmodara, son of the Kerala

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1. Even with regard to Nīlakaṇṭha's *Tantrasaṅgraha*, its introductory verse,

हे विष्णो निहितं कृत्स्नं जगत् त्वय्येव कारणे ।
ज्योतिषां ज्योतिषे तस्मै नमो नारायणाय ते ॥

seems to have a veiled reference to his patron (Netra)-Nārāyaṇa at whose instance this work too seems to have been written.

2. *Cf.*, the detailed colophon quoted above, on p. xi, from *TSS* 101, p. 180.

3. Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 114. For a ms. of this work, see Kerala Uni. Mss. Lib., 3336-B.

Dṛggaṇita author Parameśvara,[1] of the Bhārgavagotra and resident of the village of Ālattūr (Sanskritised into Aśvatthagrāma) which was situated quite near Nīlakaṇṭha's own village. In his *Ā. Bhāṣya*, as also in his other works, Nīlakaṇṭha reverentially refers to his teacher and his studies under him. He speaks of how even as a boy he stayed with his *guru* at the latter's residence prosecuting his studies ; *cf.* मया गुरुकुले वसता बाल्य एव etc. (*Ā. Bhāṣya, TSS* 110, p. 48). He also refers, often, to his teacher's views and quotes him : *cf.* प्रकारान्तेण 'चन्द्रबाहुफलवर्ग'त्यादिना श्रीमद्-दामोदराह्वयाद् गुरुमुखोद्गतेन श्लोकेनोक्ता तद्युक्तिः etc. (N's unidentified work[2] in the Trivandrum Palace Library, Ms. No. 975, transcript, p. 61) ; तच्चोक्तमस्मदाचार्यैः (*Ā. Bhāṣya, TSS* 101, p. 47) ; निबद्धं च तत् तदैव अस्मद्गुरुभिः पञ्चभिरुपजातिभिः "अर्कस्फुटेनानयनं प्रकुर्यात् etc." (*ibid.*, p. 48); तदपि—

"सर्वत्र विष्कम्भदलं श्रुतौ वा व्यासार्धके स्याद् विपरीतकर्णः ।"

इत्यस्मद्गुरुणोक्तम् । (*Siddhāntadarpaṇa-vyākhyā*, on verse 27, Ms. Trivandrum Palace Library, No. 975 ; transcript, p. 30).

Similar quotations and other references, which Nīlakaṇṭha and later authors make, proclaim Dāmodara not only as a prominent astronomer of the times but also as the author of erudite works on the subject, manuscripts of which, however, are yet to come to light. An astrological work *Muhūrtābharaṇa* is sometimes attributed to this Dāmodara.[3] But it has been shown[4] that this ascription is wrong since it is clear from the introductory verses of this work that this Dāmodara was the son[5] of Keśava of the *Bhāradvāja*-gotra, while our Dāmodara is the son of Parameśvara of the *Bhārgava*-gotra.

Nīlakaṇṭha and Parameśvara

Nīlakaṇṭha followed in the footsteps of Parameśvara, founder of the Dṛggaṇita system of astronomy in Kerala and one of the

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1. *Cf.*, the detailed colophon quoted above, on p. xi, from *TSS* 101, p. 180.
2. On this work see below.
3. *Cf.*, Vatakkumkur, *History of Sanskrit Literature in Kerala*, I. 388 ; K. Sambasiva Sastri, Introduction his edn. of *A. Bhāṣya*, *TSS* 101, Intro., p. 6.
4. *Cf.* K. Mahadeva Sastri, Preface to the *Descriptive Catalogue of Sanskrit Manuscripts in the Curator's Office*, Trivandrum, vol. V, Preface, p. iii-vi ; Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 106.
5. Brother, according to Ulloor's quotation of the particular verse, *cf. Kerala Sāhitya Caritram*, vol. II, p. 106.

foremost astronomers of the land. For him Parameśvara was not only the revered father of his *guru* but was also his *Parama-Ācārya*, by which term he generally refers to him in his works ; *cf.* यतो भार्गव-परमेश्वराचार्येण अस्मत्परमगुरुणा 'चलांशास्स्वं' (4536) इति कल्यब्दे परीक्ष्य पञ्च-दशांशपूर्तिर्निर्णीता । etc. (*Siddhāntadarpaṇa-vyākhyā*, verse 18) ; अस्मत् परमगुरुणापि सिद्धान्तदीपिकायाम् एतत् प्रतिपादितम् (*Ā.Bhāṣya*, *Golapāda*, verse 3, *TSS* 185, p. 13).

It also seems that though Nīlakaṇṭha had his regular study under Dāmodara, he had personally known Parameśvara and that the latter had instructed him on certain matters. Thus, in his *Ā. Bhāṣya*, *Gola.* 11, (*TSS* 185, p. 27) he quotes a line from Parameśvara's *Goladīpikā* (3.35) with the prefatory note : *ata evoktam asmadācāryeṇa Goladīpikāyām.*

Works of Nīlakaṇṭha

Nīlakaṇṭha has written several works which reflect his deep study and ripe scholarship in astronomy, embodying the result of his investigations in the subject and interpreting the science lucidly. A mention of his works may, advantageously, be made here.

1. *Golasāra* in three *paricchedas*, being the work edited here.

2. *Siddhāntadarpaṇa*,[1] a short work in thirty-two *anuṣṭubhs*, indicating the astronomical constants with reference to the *Kalpa* and specifying his views on the main astronomical conceptions and topics on which there are differences of opinion among authorities.

3. *Candracchāyāgaṇita*,[2] or merely *Chāyāgaṇita* under which title it is generally cited, a short work in thirty-one verses on the methods for the calculation of the moon's shadow and of the time during night on the basis of the shadow.

4. A commentary on the *Candracchāyāgaṇita*[3] above, elucidating clearly the principles and methods enunciated by him in the text.

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1. Critically ed. with Translation by the present writer, Adyar Library, Madras, 1955. Two short anonymous tracts, entitled *Siddhāntadarpaṇasiddha-paryayādayaḥ* and *Siddhāntadarpaṇastha-paryaya-bhūdināni*, added as Appendices to this edition, vouch for the popularity of this text.

2 Mss. : Kerala Uni. 5862-B, Madras R. 5185 (b).

3. Mss. : Kerala Uni 5862-B, Madras R. 5185 (b).

5. *Tantrasaṅgraha*[1] divided into eight chapters comprising 432 verses. This is a major work of Nīlakaṇṭha and is an erudite treatise on astronomy. As a work belonging to the Tantra class, it takes the commencement of the Yuga as the starting point for calculations. In the several chapters it deals with : I. Astronomical constants and general principles and conceptions. II. Calculation of the geocentric positions of the planets. III. The gnomon and calculations therewith. IV. Eclipses of the Moon and the Sun. V. Specialities in the Sun's eclipse. VI. *Vyatīpāta*. VII. The Phases of the Moon etc. VIII. *Śṛṅgonnati* of the Moon. It may be specially noted that unlike some Kerala authors who treat both the *Parahita* and *Dṛk* systems in their works, Nīlakaṇṭha treats here only of the *Dṛk* system, of which he was a great protagonist.

6. *Āryabhaṭīya-Bhāṣya*,[2] an elaborate commentary on the cryptic and sūtra-like text of Āryabhaṭa which comprehends in 121 *āryās* the fields of mathematics and astronomy. A perusal of the commentary will amply prove that it is no false claim that Nīlakaṇṭha makes when he designates his work as a '*mahābhāṣya*' and explains the method of exposition adopted by him : श्रीमदार्यभटाचार्यविरचित-सिद्धान्तव्याख्याने महाभाष्ये उत्तरभागे युक्तिप्रतिपादनपरे त्यक्तान्यथाप्रतिपत्तौ निरस्तदुर्व्याख्याप्रपञ्चे समुद्घाटितगूढार्थे सकलजनपदजातमनुजहित-निदर्शितगीतिपादार्थे सर्वज्योतिषामयन-रहस्यार्थ-निदर्शके समुदाहृत-माधवादिगणितज्ञाचार्यकृत-युक्तिसमुदाये निरस्ताखिलविप्रतिपत्तिप्रपञ्च-समुपजनित-सर्वज्योतिषामयनविद्मलहृदय-सरसिजविकासे निर्मले गम्भीरे अन्यूनातिरिक्ते गणितपाद-गतार्यात्रयस्त्रिंशद्व्याख्यानं समाप्तम् ॥ (*TSS* 101, p. 180).

In another context, reminiscising how he came to write the commentary, Nīlakaṇṭha remarks : मयाद्य प्रवयसा ज्ञाता युक्तीः प्रतिपादयितुं भास्करादिभिरन्यथाव्याख्यातानां कर्माण्यपि प्रतिपादयितुं यथाकथंचिदेव व्याख्यानमारब्धम् ॥ (*TSS* 101, p. 156). The lucid manner in which the difficult conceptions about the celestial globe and astronomical calculations are made clear, the wealth of quotations and the results of personal investigations and comparative study presented therein amply justify the appellation '*mahābhāṣya*' which Nīlakaṇṭha gives to his work.

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1. Ed. with commentary *Laghuvivṛti* of Śaṅkara Vāriyar, Trivandrum, 1958, *TSS* 188. This work has another incomplete commentary, in verse, by a Brahman of the Parakroḍa village (Mal. Tṛ-p-paraṅṅod) near Nīlakaṇṭha's own native place.

2. Ed. *TSS* 101, 111, 185 (Trivandrum, 1930, 1931, 1957).

Nīlakaṇṭha has commented only on the *Gaṇita*, *Kālakriyā* and *Gola pādas* of the *Āryabhaṭīya*, leaving out the *Gītikāpāda*, which he says is covered by the commentary on the other three sections; *cf.* तत्रेयं त्रिपाद्यस्माभिर्व्याचिख्यासिता, यतस्तद्व्याख्येयरूपत्वाद् गीतिकापादस्य एतद्व्याख्यानेनैवार्थः प्रकाशेत' (*TSS* 101, p. 1).

7. *Siddhāntadarpaṇa-vyākhyā*, a commentary by Nīlakaṇṭha on his own *Siddhāntadarpaṇa*, of which only an incomplete Ms. is available.[1] The commentary is elaborate and resembles, in diction and treatment, his *Āryabhaṭīya-bhāṣya*. It is in this work that Nīlakaṇṭha gives the actual date of his birth (see below).

8. *Grahaṇanirṇaya*, a work on the computation of lunar and scolar eclipses, possibly a short text in verse, like his other shorter works. Manuscripts of this work are yet to be discovered, but later authors and Nīlakaṇṭha himself in his *Ā. Bhāṣya* quote from this work; *cf.* तदैव ग्रहणमध्यं च । स्फुटसाम्ये तु विक्षेपकोटिमण्डलापक्रमण्डलयोः भुक्तभागसाम्यमेव स्यात् । तदुक्तं मया ग्रहणनिर्णये —

परमक्षेपकोटिघ्नः पातोनार्कभुजागुणः ।
स्वेष्टविक्षेपकोट्याप्तस्तत्क्षेपकृतियोगतः ॥

पदं यच्चापितं यच्च पातोनार्कभुजाधनुः ।
तद्विशेषं हृतं षष्ट्या गत्यन्तरहृतं क्षिपेत् ॥

पर्वान्तेऽयुक्पदे क्षेपः शोधयेद् विषमे पदे ।
एवं कृतोऽपि पर्वान्ता सूर्येन्द्वोर्ग्रहणे स्फुटम् ॥

(On *Golapāda*, 44, *TSS* 185, p. 102)

These verses are quoted also by Śaṅkara in his commentary on Nīlakaṇṭha's *Tantrasaṅgraha* (on IV. 27, *TSS* 188, p. 167) with the introductory remark तदुक्तमनेनैव ग्रहणनिर्णये ।

9. *Sundararājapraśnottara*. Sundararāja, son of Anantanārāyaṇa was an astronomer of the Tamil country contemporaneous with Nīlakaṇṭha and author of a detailed commentary on *Vākyakaraṇa* or *Vākyapañcādhyāyī* which is the basic manual on which almanacs in

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1. Ms. 975 of the Trivandrum Palace collection of mss., now preserved in the Kerala University Mss. Library. The references to pages are to a transcript supplied to me by the Palace authorities.

the Tamil districts are computed.[1] Sundararāja had the greatest respect for Nilakaṇṭha[2] whom he addressed for clarification of certain points in astronomy. Nīlakaṇṭha's detailed answers to these questions formed a regular work, *Sundararājapraśnottara*. Manuscripts of this work are yet to come to light, but both authors refer to this work. *Sundararāja* in his commentary on *Vākyakaraṇa*, V. 19, says :[3]

अत्र तु गतियोगांशकेनैव हरणं युक्तमिति श्रीमत् केरलसद्ग्रामनिवासि-नीलकण्ठार्येण त्रिस्कन्धविद्यापारदृश्वना षड्दर्शनीपारंगतेन आश्वलायनसूत्रेण गर्गगोत्रेण नवकलरु (?) जातेन गोलचूडामणिना अस्मदनुग्रहार्थे सुन्दरराजप्रश्नोत्तराख्ये ग्रन्थे प्रतिपादितम् । तेन गतियोगेनैव विभज्य स्थितिदलं ज्ञेयम् ।

Nilakaṇṭha too has a long quotation from this work in his *Ā. Bhāṣya*, *Gola*. 48, which he introduces with the words : सुन्दरराजप्रश्नोत्तरे मयोक्तमप्यत्रानुसन्धेयम् । (*TSS* 185, p. 149).

10. A *Grahaṇa-grantha*, written in continuation of Nīlakaṇṭha's *Siddhāntadarpaṇa-vyākhyā* in the Trivandrum Palace manuscript No, 975.[4] The work as available in this manuscript begins 'अथ ग्रहणम्' and without any more introduction continues : नन्वेवमपि स्वकाल एव गीतिकोक्तभगणाद्याः गीतस्य ग्रहणस्य (च) प्रत्यक्षसंवाद स्यात् । It goes on to describe the necessity of correcting old astronomical constants by observation, deals in detail with the *Śakābda-saṁskāra*, quotes the verses of his *Parama-guru* Parameśvara from his *Siddhāntadīpikā* (*Mahābhāskarīya-bhāṣya-vyākhyā*)[5] on the latter's observation of some eclipses, and after some more discussions ends abruptly. There is no doubt that this work is from Nīlakaṇṭha's pen. References to his own works, teacher etc. fully confirm this point. One of his own works is referred to in the passage thus : अत एव मया छायागणिते तत्साधनतया दृक्क्षेपानयनमुक्तम्— 'अन्त्यद्युज्या' etc. (p. 60 of the transcript). The verses quoted are from

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1. Ed. critically by T.S. Kuppanna Sastri and K.V. Sarma, K.S.R. Institute, Madras, 1962.

2. He even commences his work expressing his respect for Nilakaṇṭha ; *Cf.*, his second introductory verse, which begins : *Śrī-Nīlakaṇṭhāṅghri-niviṣṭacetāḥ* (*ibid.*, p. 1).

3. *Ibid.*, p. 119.

4. The page references, below, refer to the transcript of the manuscript supplied to me.

5. Ed. by T.S. Kuppanna Sastri, *Madras Govt. Or. Ser.* 130 (1957).

Nīlakaṇṭha's available work, *Candracchāyāgaṇita*, vv. 8-10. He refers to his grand-teacher Parameśvara and his *Ā. Bhāṣya*, too, herein : तस्मात् सिद्धान्तदीपिकोदाहृतानि ग्रहणान्यस्माभिदृष्टानि च तत्तदवसरे वक्ष्यमाणानि परमेश्वरोक्तप्रकारेण अर्कादिमध्यममानीय श्रीपत्युक्तप्रकारेण स्फुटीकृत्य कालक्रिया-गोलपादोक्ताभिरस्माभिर्व्याख्याताभिः युक्तिभिः सिद्धैः क्रियाविशेषैश्च गण्यन्ताम् । (p. 57-58 of the transcript). The *Ā. Bhāṣya* is referred also elsewhere in this work (*cf.* pp. 62, 63 of the transcript). For a characteristic reference to his teacher see : प्रकारान्तरेण 'चंद्रबाहुफलवर्गे' त्यादिना श्रीमद्-दामोदराह्वयास्मद्गुरुमुखोद्गतेन श्लोकेनोक्ता तद्युक्तिरपि आर्यभटीयान्तर्भूतैव । (p. 61 of the transcript). This *Grahaṇa-grantha*, which is primarily a treatise in prose, does not contain the verses quoted above from the *Grahaṇanirṇaya* which is obviously a different work.

11. *Grahaparīkṣākrama* (?). The well-known Kerala astrologer Puliyūr Purushottaman Namputiri has edited[1] an old, incomplete[2] Malayalam summary of a Sanskrit work under the title *Grahaparīkṣā-kramam*. The textual verses were not available to the editor and he presumed the author to be Dṛggaṇita-Parameśvara.[3] These verses are, however, found in Nīlakaṇṭha's *Bhāṣya* on the *Golapāda* of the *Ārya-bhaṭīya*, under verses 48 (*TSS* 185, pp. 132-49). It is a long tract of about 200 verses, summing up the principles and methods followed in Indian astronomy and forms a veritable handbook an the subject, and ends :

इति संक्षेपतः प्रोक्ता परीक्षा ज्योतिषामिह ।
कालमानचतुष्कस्य श्रुतस्य विवृतिस्त्वियम् ॥

It is not however definite whether this is an independent work with the title *Grahaparīkṣākrama* and quoted in extenso in the *Bhāṣya* or only forms a part of the *Bhāṣya*; the ascription of this as a separate work of Nīlakaṇṭha has therefore to remain tentative till it is supported by independent manuscript or other evidence.

Nīlakaṇṭha should have written more works than those detailed above, since there are quotations attributed to him in later works,

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1. Pub. by the Astrological Research Institute, Bombay-25, 1950.

2. The colophonic words at the end of the edition indicating its completion is only the editor's addition.

3. Vide the editor's Introduction, p. i ; see also Shri Namputiri's review and opinion of *Gaṇitaprakāśika* by K. V. A. Rama Poduval, Canannore, 1950, p. xiv.

for instance, in Śaṅkara's commentary *Laghuvivṛti* on his (N's) *Tantrasaṅgraha*, which cannot be traced to his known works. Again, the Trivandrum Palace Ms. No. 975 containing Nīlakaṇṭha's *Siddhāntadarpaṇavyākhyā* and the work on eclipses described above, has, in continuation, some incomplete tracts with no definite titles, which again, to all appearances, seem to be Nīlakaṇṭha's writings.

The *New Catalogus Catalogorum* (Madras Univ., vol. V, p. 262a) records a Ms. of *Gaṇitadarpaṇa* by Nīlakaṇṭha (*Travancore Ad. Rep., 1104*, 75). Probably, this is only his *Siddhāntadarpaṇa*. According to some,[1] Nīlakaṇṭha has composed a *Grahanirṇaya*; it is likely, however, that this is only the *Grahaṇanirṇaya* noticed above. Ulloor attributes to Nīlakaṇṭha a work called *Gaṇitayukti*: Thus, speaking about a *Bhāṣāyuktibhāṣa*, he says that "it is not the work of Kelallūr Comātiri, author of *Gaṇitayukti*."[2] This ascription is wrong and the fact is that while our author belonged to the Garga-gotra, this latter work is by an anonymous author belonging to the Bhāradvāja-gotra, as is clear from its first verse, which runs as follows :

विदित्वार्यभटप्रोक्तगोलतत्त्वेन केनचित् ।
भारद्वाजेन तन्यन्ते काश्चित् गणितयुक्तय: ॥[3]

Chronology of Nīlakaṇṭha's Works

It has already been pointed out by other scholars[4] that Nīlakaṇṭha's *Ā.Bhāṣya* is later than his *Tantrasaṅgraha* and *Golasāra* which are quoted in the former. But nothing could be said about the chronology of his other works. It is possible, however, to shed some light on this matter.

The first five works enumerated above, *viz.*, *Golasāra*, *Siddhānta-darpaṇa*, *Candracchāyāgaṇita*, the commenary thereon, and *Tantra-saṅgraha* do not refer to any other work but are, in their turn, quoted in other works of Nīlakaṇṭha. Of these, the *Tantrasaṅgraha* is the most comprehensive of the five and gives the date of its composition as 1500 A.D., *i.e.*, written when the author was

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1. *E.g.*, Vatakkumkur, *Hist. of Skt. Lit. in Kerala*, vol. I, p, 389 ; Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 117.

2. Ulloor, *ibid.*, p. 122.

3. Ms. : Madras, Mal. D. 339, pp. 83-89. Kerala Uni. Ms. 755.

4. Ulloor, *Kerala Sāhitya Caritram*, vol. II, p. 119.

fifty-six, and on these considerations it may be presumed that the other four works were written before it. The *Grahaṇanirṇaya* and the *Sundararājapraśnottara*, of which manuscripts have yet to be discovered and which are quoted in the *Ā.Bhāṣya*, have also to be ascribed to this period. This *Bhāṣya*, his mature work, Nīlakaṇṭha wrote when he was old, as he himself remarks : मयाद्य प्रवयसा ··· यथाकथंचिदेव व्याख्यानमारब्धम् । (*TSS* 101, p.156). The *Siddhāntadarpaṇa-vyākhyā* which refers to the *Āryabhaṭīya-Bhāṣya* (*cf.* on verse 25 : एतत् सर्वं मया आर्यभटीयव्याख्याने प्रपञ्चितमिति विरम्यते । p.22 of the transcript) is still later. And so also is his discursive treatise on eclipses which too refers to the *Ā. Bhāṣya* more than once : *cf.* तत्र कालक्रियापादे सूचितं मया विवृतञ्च (p. 63 of the transcript) ; एतत् सर्वं गणितपादे विस्तरेणोपपादितः (*ibid.*, p. 63).

Date of Nīlakaṇṭha (A D. 1443-1545)

Indisputable evidences are available regarding the date of our author. Śaṅkara, Nīlakaṇṭha's pupil, in his commentary on his teacher's *Tantrasaṅgraha*, points out that the first and last verses of that work contain chronograms specifying the dates of commencement and completion of the work. Thus, after giving the natural meaning of the first verse :

'हे विष्णो निहितं कृत्स्नं' जगत् त्वय्येव कारणे ।
ज्योतिषां ज्योतिषे तस्मै नमो नारायणाय ते ॥

Śaṅkara says : आचार्येण इमं श्लोकं आदितो ब्रुवता प्रथमपादेन प्रबन्धारम्भ-दिनकल्यहर्गणश्च अक्षरसंख्यया उपदिष्टः, समाप्तिसमयाहर्गणश्च 'लक्ष्मीशनिहितध्यान' इत्यन्ते भविष्यति । These two Kali dates 16,80,548, and 16,80,553 work out to Kali year 4601, Mīna 26, and 4602, Meṣa 1, both dates occurring in April 1500.

The *Siddhāntadarpaṇa* and Nīlakaṇṭha's own commentary thereon give the year and actual date of his birth : *cf.*

कलिसन्ध्यष्टमांशे स्वशतांशाढ्ये गते ततः ।
धनुर्मिथुनयोर्मध्ये प्रायशस्त्वयने उभे ॥

(*Siddh. Dar.* verse 18)

N's Com. दिव्याब्दशतमिता खलु काले सन्ध्या स्मर्यते । तस्य अष्टमांशः सार्ध-दिव्याब्दद्वादशकः । स च सौराब्दानां पञ्चत्वारिंशत्शतमितः (4500) । तस्य शतांशः

पञ्चचत्वारिंशदब्दः (45) । ततः स्वशतांशाढ्यः 'शिवशिवे'ति (4545) कल्यब्दैस्तावति याते उभे अयने उत्तरदक्षिणाख्ये प्रायशो धनुमिथुनमध्ये स्तः । तदा अयनचलनांशाः धनात्मकाः पञ्चदशसंख्या बभूवुः । प्रायिकत्वं च कलाष्टकाधिकत्वात् । यतो भार्गव-परमेश्वरार्येण अस्मत्-परमगुरुणा 'चलांशास्स्वं' (4536) इति कल्यब्दे परीक्ष्य पञ्चदशांशपूर्तिर्निर्णीता । अतः सन्ध्याष्टमांशशतांशस्य प्रायिकत्वम् । स्वजन्मकालज्ञापनार्थं चैवमुक्तम् । तदा अहर्गणश्च 'त्यजाम्यज्ञतां तर्कैः' (16,60,181) इति । (p. 14 of the transcript). Here, Nīlakaṇṭha himself says that he was born on the Kali date 16, 60, 181, which works out to A. D. 1443 Dec. (Kali 4545 Vṛścika).

That Nīlakaṇṭha lived to a ripe old age, even to be a centenarian, is attested by a contemporary reference made of him in a Malayalam work on astrology, *viz.*, the *Praśnasāra* by Mādhava, a Nampūtiri brahman of the Īñcakkāzhvā house in Kerala, who wrote his work in A. D. 1542-43. Here, Mādhava says that he could count upon reputed authorities like 'Keḷanallūr' to recommend his work : cf.

āl-āyat-ādaravil ādiyil Āttimattam
lōkōttaran punar-itinniha Keḷanāllūr |
ābhāsar allarivatuḷḷavar ādarippān
porum prasiddhi perikoḷḷavar uṇṭanekam ||

The date of composition of this work is given as Kali 4644 (A. D. 1542-43) by the following verse in the work itself :

ezhunūttorupatteṭṭāvatu Kollam atāya nāl |
varunna viṣuvad '*bhavatattvam*' (4644) *kalyabdam āyatu ||*

Rightly does Nīlakaṇṭha remark in his *Ā.Bhāṣya* : मयाद्य प्रवयसा " यथाकथंचिदेव व्याख्यानमारब्धम् । (*TSS* 101, p. 156) ; and we know of at least two more works, his commentary on the *Siddhāntadarpaṇa* and the work on eclipses, which quote the *Ā.Bhāṣya*, and which he should have written when he was still older.

Versatility of Nīlakaṇṭha

For a mere Jyautiṣika and one who had specialised only in the astronomical side of it, Nīlakaṇṭha seems to be very well read. Every page of his writings substantiate his knowledge of the several branches of Indian philosophy and culture. Sundararāja, the Tamil astronomer, calls him *ṣaḍ-darśanī-pāraṅgata*, one who

had mastered the six Darśanas[1] Nīlakaṇṭha himself informs us that he studied Vedānta under Ravi : *cf. Ravita ātta-vedāntaśāstreṇa.* He can refer to a Mīmāṁsā authority to establish a mathematical point[2] and, with equal facility, use a grammatical dictum for the same purpose.[3] Piṅgala's *Chandassūtra*[4] and the lexicons, he quotes as the occasion demands. The scriptures and the Dharmaśāstra texts also come in for citation.[5] And, also the Purāṇas[6] like the *Bhāgavata*[7] and the *Viṣṇu*.[8] As for Jyotiṣa works, Nīlakaṇṭha exhibits a surprising familiarity with a large number of them, from the *Vedāṅga-Jyotiṣa* down to contemporary treatises. He uses all types of jyotiṣa texts, *Gaṇita, Saṁhitā* and *Horā*, but as became his subject of specialisation, his quotations are mainly from texts dealing with astronomy proper. Some of the more important texts of all-India prevalence that Nīlakaṇṭha quotes are : *Vedāṅga-Jyotiṣa, Āryabhaṭīya*, the *Gargasaṁhitā, Brahmasiddhānta, Varāhamihira's Pañcasiddhāntikā, Bṛhajjātakā* and *Bṛhatsaṁhitā*, the *Sūryasiddhānta*, Śrīpati's *Siddhānta-śekhara* and Muñjāla's *Laghumānasa*. Of texts common only in Kerala may be mentioned the *Parahitagaṇita* or *Grahacāranibandhana* of Haridatta,[9] Bhāskara's *Bhāṣya* on the *Āryabhaṭīya* and his *Laghu-* and *Mahā-bhāskarīya-s*, Govindasvāmin's *Bhāṣya* on the latter and Parameśvara's super-commentary *Siddhāntadīpikā* thereon. Other works of Parameśvara like his *Āryabhaṭīya-vyākhya, Dṛggaṇitu* and *Goladīpikā* also

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1. *Cf.*, his commentary on the *Vākyakaraṇa*, V. 19 (edn., p. 119).

2. *Cf.*, *Ā. Bhāṣya*, *TSS*, 101, pp. 54, 158, *TSS* 185, p. 30 where Pārthasārathi Miśra's *Vyāptinirṇaya* and *Advaitavivaraṇa*, and *Ajitā* (com. on *Ślokavārttika*) and its commentary *Vijayā* come in for quotation. On *Golapāda* 50 (*TSS* 185, pp. 161-64), are quoted the *Ślokavārttika* and *Bṛhaṭṭīkā* of Kumārila, the *Niruktavārttika* of Padmpāda, Manu and Vyāsa.

3. For quotations from the *Vākyapadīya*, see *Ā.Bhāṣya*, *TSS* 110, p. 31.

4. See *Ā.Bhāṣya*, *TSS* 101, p. 4.

5. See Com. on *Siddhāntadarpaṇa*, verse 1, the Grahaṇa work, pp. 48, 49, and *Ā.Bhāṣya*, *Golapāda*, verse 48, where the *Taittirīyopaniṣad*, *Kālanirṇaya* of Sāyaṇa, Manusmṛti etc. are quoted.

6. See Com. on *Siddhāntadarpaṇa*, verse 1.

7. *Cf.*, *Ā.Bhāṣya*, *TSS* 110, pp.16, 26.

8. *Cf. ibid.*, p.8.

9. Ed. K.V. Sarma, K.S.R. Institute, Madras, 1954.

come in for citation as also passages from his own teacher Dāmodara. Another Kerala author whom Nīlakaṇṭha quotes profusely is Mādhava, often styled 'Golavid' who was a reputed astronomer of the times.[1] Manuscripts of several works quoted by Nīlakaṇṭha are yet to be unearthed. A detailed study of the numerous authorities quoted by Nilakaṇṭha is bound to throw much light on the history of Indian astronomy.

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Vishveshvaranand Institute,
Hoshiarpur,
'*Rakshabandhan*'
August 17, 1970.

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1. On this Mādhava (*c.* 1340-1425), who was a teacher of Dṛggaṇita-Parameśvara, see the present writer's Introduction to his edition of Mādhava's *Veṇvāroha* (Sanskrit College, Trippunithura, Cochin, 1957).

गार्ग्य-केरल

नीलकण्ठ-सोमयाजि-विरचितः

गोलसारः

QUINTESSENCE OF SPHERICAL ASTRONOMY

By Gārgya-Kerala

NILAKAṆṬHA SOMAYĀJI

QUINTESSENCE
OF SPHERICAL ASTRONOMY

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NILAKAṆṬHA SOMAYĀJI

SECTION ONE

(Salutation)

1. Hail Earth, spherical in shape, supporter of all, itself unsupported, around which revolves incessantly the celestial sphere.

(Civil days and Revolutions of the Planets)

2-5a. The Terrestrial days occurring in one-tenth of an Aeon (*Mahāyuga*) are 15,77,91,750. The (number of) revolutions, (during the same period), of the Sun and other (planets), and of the Apogee and Ascending Node of the Moon (*indu-ucca* and *indu-pātā*) are respectively :

(Sun)	4, 32, 000
(Moon)	57, 75, 332
(Mars)	2, 29, 686
(Mercury)	17, 93, 704
(Jupiter)	36, 418
(Venus)	7, 02, 227
(Saturn)	14,660
(Moon's Apogee)	48, 812
(Moon's Node)	23, 230

These (numbers) are enunciated by deduction.

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गोलसारः

प्रथमः परिच्छेदः

[मङ्गलाचरणम्]

गोलाकारा पृथ्वी[1] सर्वाधारा स्वयं निराधारा।
ज्योतिर्गोलः[2] परितो यामेव सदा भ्रमति[3] सा जयति ॥ १ ॥

[भूदिनानि ग्रहभगणाश्च]

विष्णुपदार्थ[4]त्यष्टयङ्काद्रिस्वरशर[5]भुवो दिनानि भुवः।
युगदशमांशभवान्यथ सूर्यादी[6]न्दूच्चपातभगणाश्च ॥ २ ॥

खत्रयदन्ताम्बुधयो, यमाग्निपुष्करशर्रषिशैलशराः।
षडहिषडङ्काकृतयो, वेदखमुनिपुष्कराङ्कशैलभुवः ॥ ३ ॥

धृत्यब्धिरसहुताशाः, शैलाकृत्यश्विविष्णुपदमुनयः।
वियदङ्ग[7]तर्कमनवो, यमचन्द्रगजाहिवारिधयः ॥ ४ ॥

गगनाग्निदन्तयमलान्येते युक्त्या समुद्दिष्टाः।

Mss. used : **A.** KU-C 1024 E ; **B.** KU 8358 E ; **C.** IO 6301 ; **D.** KU-C 1869 B ; **E.** Ms. from Shri Rama Varma Maru Thampuran, Cochin ; **F.** KU 5867 B ; **G.** GOML, Madras, R 5151a.

1. E पृथिवी
2. D गोलाः
3. D भ्रमन्ति
4. E om. र्थ
5. A. C रा, corrupt.
6. A. B दि for दी, corrupt.
7. E दङ्क, corrupt.

(Positions of the Higher Apses)

5b-6a. (The following are) the positions of the Higher Apses (*Mandocca*) (of the planets) other than the Moon, in degrees: (Sun) 78°, (Mars) 127°, (Mercury) 220°, (Jupiter) 162°, (Venus) 80°, (Saturn) 240°.

(Positions of the Ascending Nodes)

6b. (The following) multiplied by 10 are, respectively, the positions in degrees of the Ascending Nodes (*Pāta*) of the planets beginning with Mars: (Mars) 4 (x 10=40°), (Mercury) 2 (x 10=20°), (Jupiter) 8 (x 10=80°), (Venus) 6 (x 10=60°), (Saturn) 10 (x 10=100°).

(Maximum Mean Latitudes of planets)

7a. (The following) multiplied by 10 give the Maximum Latitudes (of the planets) in minutes: (Moon) 27 (x 10=270'), (Mars) 9 (x 10=90'), (Mercury) 12 (x 10=120'), (Jupiter) 6 (x 10=60'), (Venus) 12 (x 10=120'), (Saturn) 12 (x 10=120').

(Epicycles of the Equation of Apses of the planets)

7b. (The following give in units),[1] the magnitude of the circumference of the *Manda* circles (of the planets beginning) from the Sun: (Sun) 3, (Moon) 7, (Mars) 16, (Mercury) 14, (Jupiter) 8, (Venus) 3, (Saturn) 10.

(Epicycles of the Equation of Conjunction of the planets)

8. (The following give, in units), the magnitude of the circumference of the *Śīghra* (Epicycle of the Equation of Conjunction of the planets) beginning with Mars, (in the odd quadrants): (Mars) 53, (Mercury) 31, (Jupiter) 16, (Venus) 59, (Saturn) 9.

(The same) reduced, respectively, by 2, 2, 1, 2 and 1 are the same in the even quadrants. (*i.e.*, Mars 51, Mercury 29, Jupiter 15, Venus 57, Saturn 8).

(Diameters of the Sun, the Moon and the Earth)

9. The diameters of the Sun, the Moon and the Earth in yojanas as given by the learned are: (Sun) 4410, (Moon) 315, and (Earth) 1050.

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1. The epicycles are given in a unit that makes the circle equal to 80 parts. (See v. 11 b, below). Thus, when the circle is measured in degrees, the unit of measurement for the epicycles in 4½ degrees.

[मन्दोच्चानि]

गजशैलाः[1], शैलार्काः, खाकृतयो, द्व्यङ्ग[2]भुवः, खमातङ्गाः ॥ ५ ॥

खजिना, मन्दोच्चांशा विविधूनां;

[ग्रहाणां पातस्थानानि]

पातभागास्तु ।

जलधि,-[3]यमा-ऽहि,-रस,-दिशो दशाहता भूमिजादीनाम् ॥ ६ ॥

[परमविक्षेपाः]

[4]तारा,-ऽङ्क,-रवि,-रसा,-ऽर्काः, प्रभाकराः क्षिप्तिलिप्तिका दिग्घ्नाः ।

[मन्दवृत्तपरिधयः]

[5]सूर्यान्भृदुवृत्तांशाः त्र्य-ऽश्वा-ऽष्टी-न्द्रा-ऽहि-रामा-ऽऽशाः ॥ ७ ॥

[शीघ्रवृत्तपरिधयः]

शैघ्रे भौमादीनां गुणबाणाः, शशिगुणा, रसक्षितयः ।

एकोनषष्टिर्, अङ्काः; द्विद्व्येकद्व्येकवर्जिता युग्मे[6] ॥ ८ ॥

[सूर्यचन्द्रभुवां व्यासाः]

दिग्युगवेदा, बाणैकवह्नयः, खेषुपंक्तयो व्यासाः ।

रविचन्द्रमेदिनीनामुद्दिष्टा योजनात्मकाः सद्भिः ॥ ९ ॥

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1. C om. शैलाः by haplography.
2. D. E द्व्यग, corrupt.
3. E रस for यम, wrong.
4. D. E ताराङ्कार्करसरविप्रभाकरा
5. D. E भौमान्मृदु, wrong.
6. C In the microfilm used, one page was missing, which contains the portion from ग्मे to भुवि प्र in II. 4d.

(The motions in terms of signs etc.)

10. The (number of) revolutions (given above) multiplied by 12 give the *rāśis* (signs), these multiplied by 30 give the degrees, and these (again) multiplied by 60 give the minutes. Seconds and further (denominations) are obtained by these in a similar manner (*i.e.*, by multiplying further by 60 each).

(The Orbits etc. of the planets)

11a. The orbit of a planet (in yojanas) is (given by) the number of minutes of arc of the Moon (got in verse 10) multiplied by 10 and divided by the number of revolutions of the planet (given above in verses 2-5a).

11b. The yojana measure of the epicycles (given in vv 7b-8) are in units of the 80th part of that (*i.e.*, of the moon's orbit).[1] The declination is a fifteenth part.[2]

Thus is the First Section in the

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1. This means that the parts mentioned in vv. 7b-8 are in units of $4\frac{1}{2}$ degrees.

2. This is equal to saying that the obliquity of the ecliptic is 24 degrees.

[राश्यादिमानम्]

भगणा द्वादशगुणिता भानि, त्रिंशद्गुणितानि तान्यंशाः ।
ते षष्टिगुणाः कलिका; विलिप्तिकाद्यास्ततस्तद्वत् ॥ १० ॥

[ग्रहकक्ष्याः]

शशिलिप्ता दशगुणिता स्वभगणभक्ता ग्रहस्य कक्ष्या स्यात् ।
तदशीत्यंशैरुक्तं वृत्तं, तिथ्यंशसम्मिता[1] क्रान्तिः ॥ ११ ॥

[2]इति [गार्ग्य-केरल-नीलकण्ठ-विरचिते]

गोलसारे प्रथमः परिच्छेदः ॥

---

1. A. B संयुता
2. D. E do not have this colophon here. In them, the First Pariccheda includes also nine verses of the next Pariccheda, after which this colophon is given.

Section Two

(Situation of the Cetestial sphere)

1. The earth, a regular sphere, composed of mud etc. and sustaining itself by its own power and situated at the middle of the celestial globe supports all things around it.

2. Since all weighty things fall on the earth from the sky all around, the Earth is 'down' from everywhere and any direction opposite to it (*i.e.*, pointing away from the Earth) is 'up'.

3. The atmosphere extends some yojanas into the sky, all round the earth. Above that, the wind known as *Pravaha* blows, causing the celestial bodies to revolve.

4. That region upon the earth where *all* the stars revolving in that (*Pravaha*) region can be seen rising one after another, and where the Pole stars are (exactly) on the two sides, is called the region of Zero latitude (*i.e.*, the Equitorial region).

5. The revolving vertical circle there (*i.e.*, the Prime Vertical at that region) is called the *Ghaṭikā-maṇḍala*[1] (Hour Circle). On both sides of that are the different fixed Diurnal Circles of the heavenly bodies.[2]

6. The stellar sphere is constantly revolving westwards with the two Celestial Poles as the apices and is rotated by the *Pravaha* wind (completely once) in (a period containing) *Prāṇa-s* equal in number to the minutes of arc in a circle, (*viz.*, 21,600), (*i.e.*, in one sidereal day).[3]

7. This celestial globe is divided into twelve *rāśis*; the central great circle, (called *Apakrama-vṛtta* or the Ecliptic), is inclined to the Celestial Equator[4] so that one half of it lies to the north of it and the other to the south.

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1. It is so called because time, in units like the *ghaṭikā*, are measured on it. The term *Viṣuvan-maṇḍala* (Equinoctial) is also applied to this great circle.

2. These are known by the name *dyu-vṛtta* or *ahorātra-vṛtta*.

3. A sidereal day is equal to 60 *nāḍikās*, a *nāḍikā* equal to 60 *vināḍikās* and a *vināḍikā* equal to 6 *prāṇas*; hence, one day is equal to 60 x 60 x 6=21, 600 *prāṇas*.

4. This obliquity is equal to 24°. See above Sn. I, verse 11d.

द्वितीयः परिच्छेदः

[गोलपरिस्थितिः]

[1]समघनवृत्ता भूमिः स्वयैव शक्त्या धृता मृदादिमयी।
ज्योतिर्गोलकमध्ये बिभर्ति विश्वं समन्ततो वस्तु ॥ १ ॥

द्रव्याणि गुरूणि यतः पतन्ति भूमौ समन्ततो नभसः।
अध एव सर्वतो भूस्, तस्मात् प्रतियोगिनी दिगूर्ध्वाख्या ॥ २ ॥

कतिपययोजनपरिमितम् अतस्समन्ताद्विहायसि विहायः।
भ्रमति ह्यूर्ध्वं वायुः प्रवहाख्यो भ्रामयन् विहगान् ॥ ३ ॥

तत्र भ्रमन्ति यत्र क्रमेण दृश्यानि भानि सर्वाणि।
पार्श्वस्थे [2]ध्रुवतारे निरक्षसंज्ञो भुवि प्रदेशः सः ॥ ४ ॥

घटिकामण्डलमाहुस्तत्र यदधऊर्ध्वगं भ्रमद् वृत्तम्।
अभितोऽपि च तद् भ्रमतां भवन्ति नाना ध्रुवा द्युवृत्तानि ॥ ५ ॥

प्रत्यक् भ्रमति भचक्रं मेधीकृत्य ध्रुवौ[3] नियतम्।
चक्रकलासमसंख्यैः प्रवहेण भ्राम्यते च तत्प्राणैः ॥ ६ ॥

द्वादशराशिविभक्तो भगोल इह, तस्य मध्यवलयं[4] यत्।
अपयातं घटिकाख्यात्[5] तदर्धशस् सौम्ययाम्यदिशोः[6] ॥ ७ ॥

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1. F and G omit the preceding portion ; in them the work commences only from here.
2. G om. ध्रु; gap indicated.
3. G ध्रुवे, corrupt.
4. A.B मध्यमवलयं ; *i.e.*, म extra.
5. G om. त्, wrong.
6. A.B दृशोः, wrong.

8. This (circle, *viz.*, the Ecliptic) is divided into *rāśis* (segments of 30°), *bhāgas* (degrees) and *kalās* (minutes) by circles perpendicular to it, so that, a body, wherever it may be seen (on the Celestial sphere) lies in one of the *rāśis*, *Meṣa* etc.[5]

9. The reckoning of *Lagna* (Rising point of the Ecliptic) is in relation to the central circle of the revolving celestial sphere, (*viz.*, the Ecliptic). Hence, at the moment of the rising of the *Lagna* in a particular *rāśi*, a star in a different *rāśi* may also be rising.[6]

10. The planets move in their orbits with centres at the Higher Apses of their Epicycles of the Equation of the centre. For the Sun and the Moon, the centre of the celestial sphere is the centre of the above epicycles.

11. For the other (planets), the centres (of their *Manda* circles) are on (the circumference of) their *Śīghra* circles concentric with the Ecliptic. One half of their *Manda* circles is deflected northwards from the Ascending Node and the subsequent half southwards.

12. The Moon and other (planets) have their respective orbits increasing according to (the changes in their *Manda* (circles).[7] And for all (planets), the increase and decrease of the circumference of the *Manda* circles depend upon their hypotenuse.[8]

---

5. The Ecliptic is divided into 12 *rāśis* called *Meṣa* etc., commencing from a point situated near the junction-star called Zeta Piscium in the asterism of Revatī.

6. This may happen in the case of stars which are removed from the Ecliptic.

7. That is, the hypotenuse got in the *Manda*-operation is the radius of the orbit on which the planet in measured after this operation. This is a peculiarity of the school of Āryabhaṭa.

8. This is another peculiarity of the Āryabhaṭan school. The mutual dependence is resolved by resorting to what is called *aviśeṣakriyā* or successive approximation.

तत्सम्मतिर्यग्वलयैः प्रविभज्यन्तेऽत्र राशिभागकलाः।
यत्र क्वापि च दृष्टं ज्योतिर्मेषादिराशिगं तस्मात्[1] ॥ ८ ॥

लग्नव्यवहारस्तु भ्रमद्[2]भगोलस्थमध्यवृत्तवशात्।
स्वाधिष्ठितात्तथोद्यति भिन्ने राशावुडूदयोऽपि[3] भवेत्[4] ॥ ९ ॥

निजमन्दपरिधिगोच्चं केन्द्रीकृत्य[5] भ्रमन्ति कक्ष्यासु।
विहगाः रविचन्द्रमसो[6]र्भगोलमध्यं स्वमन्दवृतिमध्यम्[7] ॥ १० ॥

अपमण्डलमध्यस्थ[8]स्वशीघ्रवृतिसंगतोच्चमन्येषाम्।
पाताद्[9] विक्षिप्तमुदङ्मृदुवृत्तार्धं, ततोऽन्यतोऽन्यार्धम्[10] ॥ ११ ॥

चन्द्रादीनां मन्दानुसारतः स्वस्वकक्ष्याः स्युः।
क्षयवृद्धी सर्वेषां परिधेर्मन्दिस्य तु स्वकर्णवशात् ॥ १२ ॥

---

1. C. F. G राशिगस्तस्मात्
2. C भ्रमन्
3. G gap for वुडू ; हि for पि
4. D. E. F. G indicate the end of Pariccheda I, here, with the colophon, इति गार्ग्यकेरल-नीलकण्ठ-विरचिते गोलसारे प्रथमः परिच्छेदः (D. E add यज्व after नीलकण्ठ).
5. D मेधीकृत्य
6. E मसो
7. D. E केन्द्रम् for मध्यम्
8. A. B. C. मध्यस्य, corrupt.
9. A. B. C पादात्, wrong.
10. After उदङ्, some mss. are corrupt : A.B.C. वृत्ताद्यार्धमन्यतोन्यार्धम् ; F.G. वृत्तार्धं ततोमन्यतोन्यार्धम्।

13. Of the planets which move, each in its own orbit, eastwards (in relation to the stars fixed on the celestial globe which, as a whole, is moving westwards), the motion in yojanas is equal. But their (angular) motion in minutes is different, (for the same planet at different positions) as also from one another's (owing to variance in the hypotenuse and the magnitude of the orbits, respectively).

14. To fix the mid-day for these (planets) which move (apparently) westwards, a fixed north-south lying great circle situated equally on both sides of (mid-) day and night is presumed.

15. This (circle) is the horizon at the equator, and is called *Unmaṇḍala* elsewhere. In regions other than the equator, the *Samamaṇḍala* (which coincides with the Hour Circle at the equator), too, varies from place to place, (*i.e.*, in different terrestrial longitudes).

Thus is the Second Section in the

QUINTESSENCE OF SPHERICAL ASTRONOMY

by Gārgya-Kerala Nilakaṇṭha

प्राचां(?प्राचीं)[1] भ्रमतां स्वे स्वे कक्ष्यावलये[2] तु योजनैस्तुल्या ।
लिप्ताभोगाद्[3] भिन्ना गतिर्ग्रहाणां मिथो वापि ॥ १३ ॥

प्रत्यग् भ्रमतां तेषां दिनार्धक्लृप्त्यै[4] प्रकल्प्यते स्थायि ।
वलयमुदग्दक्षिणतः समपार्श्वस्थं [5]च दिवसनिशोः ॥ १४ ॥

एतन्निरक्षदेशजम् उन्मण्डलमवनिजं (?अवनिजमुन्मण्डलं)[6] ततोऽन्यत्र ।
सममण्डलमपि भिन्नं घटिकावृत्तात् स्वदेशवशात् ॥ १५ ॥

इति गार्ग्य-केरल-नीलकण्ठविरचिते[7]
गोलसारे द्वितीयः परिच्छेदः ॥

---

1. All mss. read प्राचां ; the word ought to be प्राचीं ।
2. D कक्ष्यावृत्ते
3. A. B. C कक्ष्याभेदाद् ; D कक्ष्याभेदैः ; E लिप्ताभेदाद् ।
4. G om. क्लृ; gap indicated.
5. G om. च दिव; gap indicated.
6. All mss. read उन्मण्डलमवनिजम् ; the interchange of the words would make the meaning straight and clear.
7. A. B. C त- for ते ; E reads the entire colophon as इति द्वितीयः परिच्छेदः ।

SECTION THREE

(Introductory)

1. By the motion of one of the planets, whose motions are thus related, the motion of another is possible to be computed, and, thus, all the motions, by the inter-relationship[1] of the motions.

2. In order to get, on the stellar sphere, the motion of the planets which are moving in their own separate orbits, the R Sine, the R Versine etc.[2] are required to be known. Therefore, I shall give, hereunder, the method of knowing them.

(The Pythagoras)

3-4a. Making a square equal to the base (of a right-angled triangle) and another equal to the perpendicular, coincide, so that two right angles come together, and marking points on the base at a distance equal to base-minus-perpendicular, draw, from the corners, lines equal to the hypotenuse that is to be found.

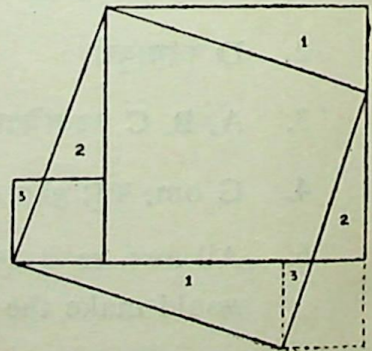
4b. Determining the triangles formed by the lines, draw them off and attach them (to the sides).

5. Then, the square formed by the equal hypotenuses is seen equal to the square on the hypotenuse (of the right angled triangle). Therefore, it is proper to say that the sum of the squares on the base and perpendicular is equal to the square on the hypotenuse.[3]

---

1. The relationship is given in I. ii.

2. If the arc of a circle is taken as bow (*cāpa*), the chord is the bow-string (*jyā*). But it is customary to take the half-chord as the R sine of the half-arc. The arrow is the R versine.

3. The fig. illustrates 3-5. The strips 1, 2, 3, cut off from the side-squares exactly fits the strips 1, 2, 3, in the hypotenuse-square.

तृतीयः परिच्छेदः

[उपोद्धातः]

एवं नियतगतीनां गत्या कस्यचिदिहान्यगतिमानम् ।
अनुमीयते च,[1] गतयो,[2] ज्योतिर्भुक्तेः परस्परं नियमात् ॥ १ ॥

यत्र क्वापि भ्रमतां नभश्चराणां भगोलगतिसिद्ध्यै ।
ज्याबाणादि ज्ञेयं; तस्मात्तदुपायमिह वक्ष्ये ॥ २ ॥

[भुजकोटिकर्णसम्बन्धः]

दोःसमचतुरश्रं यत्, कोटीतुल्यं[3] च, ते उभे श्लिष्टे ।
कृत्वा, [4]तत्कोणयुतेर्दोःकोटयन्तरसमान्महत्यनयोः ॥ ३ ॥

कुर्यात् प्रतिकोणान्तं जिज्ञासितकर्णसम्मिते रेखे ।
रेखायेगात् त्र्यश्रे निष्कृष्य भ्रामयन् च संदध्यात् ॥ ४ ॥

समकर्णं[5] चतुरश्रं जिज्ञासितकर्णबाहु भवति तदा ।
दोःकोटिवर्गयोगो वर्गः कर्णस्य युज्यते तस्मात् ॥ ५ ॥

---

1. D. E. F. G व for च
2. D. E. F. G गतया for गतियो
3. C तुलं
4. E दोःकोण, wrong.
5. E समकर्णा, wrong.

(The R Sines etc. graphically)

6. In a circle, making the radius the base (of a triagle) and the other two sides equal to it, and dropping a perpendicular from the intersection of the two sides, (*viz.*, the vertex), the two segments of the base (thus formed) are each equal to half the side, (*i.e.*, the radius).

7. The segment itself is (thus seen to be) the R Sine of the remaining arc of the quadrant. Therefore, R Sine one *rāśi*, *i.e.*, 30°, is half the radius.

8-9a. The R Cosine related to it is the perpendicular, (which is thus the R Sine of 60°). The hypotenuse of (the triangle having for its sides) the two half-chords, is the radius. The radius-minus-R Cosine is the arrow, (*i.e.*, R Versine), referring to the R Sine. Then, from the hypotenuse of these two, (*viz.*, the R Sine and R Versine), R Sines (15°, 7½°) etc. should be found by the repeated working in the circle.[1]

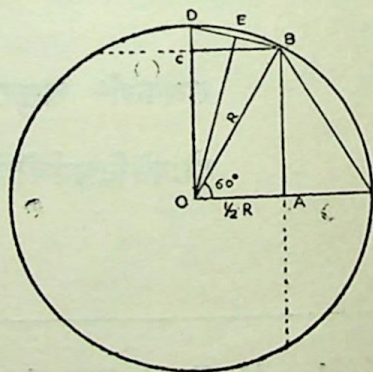
(The approximate arc and the circumference)

9b. The length of the arc is approximately the square-root of the sum of the square of the R Sine and four-thirds the square of the R Versine.[2]

10. Thus, the arc forming some definite fraction of the circumference should be chosen as the arc (for intervals of which the tabular R Sines are given). Of these arcs, (two sets of) R Sine differences are inter-related by the two R Sines at the middle of the sets, and the next difference also, situated on the same side, in the same manner, by ths R Sine at the junction of the (related) two arcs.[3]

---

1. See fig.

   $OA \approx BC = R \sin 30°$
   $AB = OC = R \sin 60° = R \cos 30°$
   $CD = R \text{ versine } 30°$.
   $DB^2 = CD^2 + BC^2$
   $DB/2 = DE = R \sin 15°$. And so on.

2. *I.e*, $\text{arc} = \sqrt{4/3(\text{R Versine})^2 + (\text{R Sine})^2}$.

If $R\theta$ is the arc, where θ is in radians, we have the formula correct to θ^5. This formula has a two-fold purpose. A small arc can be taken as its R Sine itself. The sum of the small arcs is the circumference.

3. This means, that the R Sine and its adjacent R Sine differences are inter-related, so that each R Sine can be computed successively by working as instructed in verses 13-14, following.

[भुजज्यादिकम्]

समवृत्ते व्यासार्धं कृत्वा भूमिं, भुजे च[1] तत्तुल्ये ।
लम्बं च भुजायोगाद्, बाह्वर्धसमे तदाबाधे ॥ ६ ॥

आबाधैवा[2]र्धज्या परिधेः पादेऽत्र[3] शिष्टचापभवा ।
राशेरर्धज्या सा व्यासार्धदलेन सम्मिता तस्मात् ॥ ७ ॥

तस्याः कोटिर्लम्बः, कर्णो व्यासार्धमर्धमौर्विकयोः ।
कोटयूनं व्यासार्धं बाहोर्बाणस्, ततस्तयोः कर्णात् ॥ ८ ॥

अर्धज्यादिकमेवं युक्त्या नेयं मुहुर्मुहुर्वृत्ते ।

[आसन्नमानचापस्य परिधिः]

सत्र्यंशादिषुवर्गात् ज्यावर्गाढ्यात् पदं धनुः प्रायः ॥ ९ ॥

एवं परिधेरंशो ग्राह्यः कथंचिदेव[4] चापतया ।
तेषु तु खण्डज्ये तन्मध्यज्याभ्यां परस्परं नियते ॥ १० ॥

खण्डान्तरमपि चापद्वयसन्ध्यग्रज्यया समानदिशा ।

1. E तु for च
2. E र्वा, wrong.
3. E पारेऽत्र, wrong.
4. E, G कथितश्चिदेव

11b. The circumferences are also taken as divided into minutes in a circle.

12a. If the diameter is 113 units in length, the circumference (very closely) approximates to 355 units in length.[1]

12b-13a. Whatever thing, by whatever means, in whatever manner is known to be of whatever form, that, by that means, and in that manner, indicates a similar thing of the same form.[2]

(The tabular R Sines by computation)

13b-14a. To get the R Sines successively previous to the one already found, multiply this R Sine by twice the very last difference, and divide by the radius. The result plus the difference (using which this R Sine has been found) is the difference to be subtracted from this R Sine to get the next previous R Sine.[3]

14b. The R Sine of any desired arc in excess or defect (of a given arc for which the tabular R Sine is given) can be found by using the hypotenuse, the base, the perpendicular etc., (in the manner mentioned already).[4]

---

1. *I.e.*, π is very nearly equal to 355/113.

2. This refers to the similarity of figures and operations.

3. The very last difference is supposed to be known, this being the difference between the radius and the penultimate R Sine, which itself is the R Cosine of the first R Sine, which is again taken equal to the corresponding arc. For example, if there are 24 R Sines in the quadrant, and if minutes of arc are taken as units, the radius is 3438 and is the 24th R Sine. The 23rd is $\sqrt{3438^2-225^2}=3430.6$, and the last difference is 7.4. Twice this is 14.8. The difference between the 23rd and the 22nd is $3431 \times 14.8 \div 3438 + 7.4 = 22$. Subtracting 22 from 3431, the 22nd is 3409. The difference between the 22nd and 21st is $3409 \times 14.8 \div 3438 + 22 = 37$. The 21st is $3409 - 37 = 3372$. The difference between 21st and 20th is $3372 \times 14.8 \div 3438 + 37 = 51$. The 20th is $3372 - 51 = 3321$. And so on.

4 This is for securing accuracy. Otherwise, interpolation by the differences would suffice. The formula is: $R \sin(\theta \pm \alpha) = R \sin\theta . \cos\alpha \pm R \cos\theta . \sin\alpha = R \sin\theta \left(1 - \frac{\alpha^2}{2}\right) \pm \alpha R \cos\theta$, where α is in radians, and sufficiently small. It is this formula that is the basis for the instruction in verses 13b-14a.

चक्रकलाप्रविभक्तान्यखिलान्यपि मण्डलानि कल्प्यन्ते ॥ ११ ॥

विश्वैकसमो व्यासः परिधेः [1]प्रायोऽर्थबाणगुणभागाः ।

यद्येन यथा नियतं यथादृशं[2] यादृशेन विदितमिह ॥ १२ ॥

तत् तस्य तथा गमकं तथाविधं तादृगन्यत्र ।[3]

[ज्यानयनम्]

द्विघ्नान्त्यखण्डनिघ्नात् तत्तज्ज्यार्धात्[4] त्रिभज्याप्तम् ॥ १३ ॥

अन्त्यादिखण्डयुक्तं त्याज्यं स्यात् पूर्वपूर्वगुणसिद्धयै ।

न्यूनाधिकचापज्याश्रुतिदोःकोटयादिभिस्त्व[5]भीष्टज्या ॥ १४ ॥

---

1. G प्रायोऽर्थबाण has strayed down after अन्त्या, below in v. 14.
2. E. G यथाविधं
3. E. F. G तादृशोऽन्यत्र
4. A,B निघ्नात्तज्ज्यार्धात्, wrong.
5. G om. स्त्व ; gap indicated.

15. The anomaly forming the difference between the planet and its apogee, and measured by the known planet's circle, (whether mean or *Śīghra*,) is (ultimately) measured by the minutes on the orbit of the knowable (*i.e.*, true) planet. And there is difference between the two.

16. The orbit is measured by the base and perpendicular on the *Manda*-circle centered at the centre of the orbit, and measured by the circle of the hypotenuse.

17a. Or, it is also measured by the radius of the orbit got from the true base and perpendicular.

17b. It is this hypotenuse circle that is deflected (from the ecliptic), since the deflection (giving the latitude) is that of the planet on this.

18. Even there, the deflection is measured, not in yojanas, but by itself, (*i.e.*, the angle). Therefore, it is not got by the hypotenuse, since it is measured on a circle always even (*i.e.*, of unchanging radius.)

19-20. This is on the *Śīghra* circle (in the case of Mercury and Venus). When this is projected on the orbit, the resulting perpendicular circle is to be got. The hypotenuse (of the equation of conjunction) is to be got by using the two results, (*i.e.*, R Sine and R Cosine) of the orbit, formed by the segments of the motion of the planet, of circles varying according to the perpendiculars got from the deflection as base, and multiplying by the hypotenuse, and dividing by the radius. The R Sine (of the equation of conjunction) multiplied by the radius, and divided by the above is the R Sine forming the result, (to be applied in the last operation).

विदितविहङ्गमवृत्तप्रमिता ग्रहतत्तदुच्चविवरभुजा ।
वेद्यग्रहवलयोद्भवलिप्ताभिर्मीयते, भिदा च तयोः ॥ १५ ॥

कक्ष्यामण्डल[1]मध्यस्वमन्दवृत्तस्थबाहुकोटिभ्याम् ।
श्रुतिवृत्तप्रमिताभ्यां तन्मानेनात्र मीयते कक्ष्या ॥ १६ ॥

स्फुटभुजकोटिभ्यां वा परिधिव्यासार्धतोऽपि तन्मानम् ।
श्रुतिवृत्तमिदं क्षिप्तं ह्यत्रत्यग्रहवशाद्यतः क्षेपः ॥ १७ ॥

तत्रापि स्वप्रमितः क्षेपो, न तु[2] योजनैः समानतया ।
तेन न कर्णे[3]नाप्यः, प्रमितः स हि कक्ष्यया सदा समया ॥ १८ ॥

[4]एतत्कक्ष्या शंघ्रे[5] क्षिप्तेऽस्मिन् कोटिमण्डलं च ततः ।
कर्णघ्नत्रिज्याप्तक्षेपभुजामान्द[6]कर्णकोटिकया ॥ १९ ॥

विहगभ्रमवलयांशैरुदितात् परिधेः फलाभ्यां च ।
साध्यः कर्णस् , तेन त्रिज्याघ्नाद् दोःफलात्तु विवरभुजा ॥ २० ॥

---

1. A. B. C. add an extra वृत्त here, wrongly.
2. A. B नतिः ; C. नति ; wrong.
3. G om. र्णे; gap indicated.
4. G om. ए
5. C कक्ष्यश्शीघ्रे, corrupt.
6. E मन्द for मान्द

21. Getting the true planet in this manner is only for the two, (*viz.*, Mercury and Venus). For Mars, Jupiter and Saturn, the perpendicular projected from the hypotenuse forming the distance between the earth and planet, is the hypotenuse, and the base is the deflection mentioned.

22. This base, multiplied by the radius and divided by the distance between the earth and planet is the true (*i.e.*, geocentric) latitude. Therefore, the latitude got on the *Manda* circle, multiplied by the *Manda*-hypotenuse is divided by this (*viz.*, the distance between the earth and the planet.)

23. Or, the hypotenuse is first to be got, using the radius of the mean planet's orbit. In getting here the perpendicular related to that, the latitude got by the *Manda*-circle is the true base.

24. Here, in the case of Venus and Mercury, their mean is corrected ley the equation of the centre. The latitude also is got from this, but this being applied to the apsis of conjuction inversely.

25. But since the orbit is smaller than the *Śīghra* circle, it, (*i.e.*, the latitude) is multiplied by the perpendicular got from the *Manda*-hypotenuse and the latitude, (taken as base), and divided by the radius, to become true.

26. The deflection listed by the wise (*i.e.*, the authoritative writers) is to be multiplied by the radius and divided by the final result. Here, the distance between the earth and the (true) planet is to be taken as the final result. Therefore, it, (*i.e.*, the latitude), becomes true by that.

27. The mean sun corrected by their (*i.e.*, of Mercury and Venus) equation of conjunction, is their true position. Their yojana measures are to be multiplied by their true distances and their *Manda*-hypotenuse and divided by their distances above.

एवमिह स्फुटसिद्धिर्द्वाभ्यामेवारमन्दजीवानाम् ।
[1]भूग्रहविवरश्रवणे कोटिः कर्णो भुजोक्त[2]विक्षेपः ॥ २१ ॥

सैव भुजा त्रिज्याघ्ना भूग्रहविवरोद्धृता स्फुटः क्षेपः[3] ।
मान्दश्रुतिनिघ्नोऽतो[4] मान्दः क्षेपो[5] विभज्यतेऽनेन ॥ २२ ॥

विदितग्रहवलयमितात् परिधेर्व्यासार्धतोऽथवा कर्णः ।
तस्य च कोटित्वेऽत्र[6] क्षेपो मान्दो भुजा ततः स्पष्टा[7] ॥ २३ ॥

प्राग्वन्मान्द[8]फलेन स्वमध्यमं स्पष्टमत्र बुधसितयोः ।
[9]तत एव च विक्षेपः पुनः स्वशीघ्रोच्चयोर्विपर्यासः[10] ॥ २४ ॥

अल्पतया कक्ष्यायाः शैघ्राद् वृत्तात्तदाहृत्य ।
मन्दश्रुतिविक्षिप्त्योः[11] कोट्या[12] त्रिज्याहृतं स्फुटं तदिह ॥ २५ ॥

क्षेपो हि बुधैः पठितस्त्रिज्यानिघ्नोऽन्त्यफलभाज्यः ।
भूग्रहविवरार्धमिहाप्यन्त्यो ग्राह्यः स्फुटश्च[13] ततः ॥ २६ ॥

शीघ्रफलेनैव रवेः संस्कृतमिह मध्यमं स्फुटं[14] तु तयोः ।
स्वक्षितिविवरघ्नं तद्योजनमपि केवलान्त्य[15]फलभाज्यम् ॥ २७ ॥

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1. E alone has this reading. The reading in the other mss., being दोर्ग्रह, seems to be corrupt.
2. A क्तं for क्त
3. E स्फुटक्षेपः
4. G (अ)सौ for (अ)तो
5. E मन्दक्षेपो; G मान्दक्षेपो
6. A. B कोटिक्षेत्र-; C कोटिक्षेत्रे, corrupt.
7. G स्पष्टः
8. F. G मन्द for मान्द
9. D line broken :···एव···विक्षेपा पुनस्व···घ्रोच्चयो विपर्यासः ।
10. D. E The further portion of the work, *viz.*, verses 25-30, missing.
11. C विक्षिप्तेः
12. F. G कोट्यां
13. C ग्राह्यस्फुटश्च; G स्फुटञ्च
14. G मध्यमस्फुटं
15. A. B. C केवलं तु, corrupt.

28-29a. The (motions of the) planets on the stellar sphere are thus ruled by motions caused multifariously. The motions of these are ruled by those. The inter-dependence is, thus, resolved by resorting to successive approximation.

29b. The motion caused by the *Pravaha* wind, (*i.e.*, the diurnal motion), of the stellar sphere, (*i.e.*, the sidereal day,) being uniform, all the motions can be measured by this motion as unit.

30. On the celestial sphere, the intersection, (called the First Point of Aries), of the hour-circle (*i.e.*, the Celestial Equator) and the ecliptic, oscillates east-wards and west-wards. The stellar sphere is raised up by the rising up of the moon, along the line joining the sun and Rāhu.

Thus is the Third Section in the
QUINTESSENCE OF SPHERICAL ASTRONOMY
by Gārgya-Kerala Nīlakaṇṭha

बाहुकरण(?बहुकारण)गतिकत्वादेवं[1] नियता ग्रहा भगोलगताः ।
कतमेन चिदेवैषां ज्ञेयः कालस्तु[2] तद्गति[3]कालात् ॥ २८ ॥

इत्यन्योन्याश्रयताप्यसकृत्क्रियया निराक्रियते ।
समसमयत्वात् प्रवहभ्रमणस्यानेन ते परिच्छेद्याः ॥ २९ ॥

घटिकापक्रममण्डलयोगश्चलतीह पूर्वपश्चिमयोः ।
रवितमसोः सूत्रेणोद्गच्छति चन्द्रोच्चतो भगोलोऽपि ॥ ३० ॥

इति गार्ग्य-केरल-नीलकण्ठविरचिते[4]
गोलसारे तृतीयः परिच्छेदः ॥

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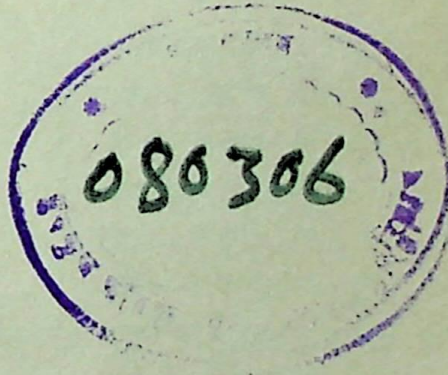
1. G देव
2. A. B. C ज्ञेयकालस्य
3. G तद्गतिः
4. A.B.C विरचित-; F. G read merely तृतीयः परिच्छेदः ।

गार्ग्यकेरल-नीलकण्ठसोमयाजिकृत-
गोलसारान्तर्गत-
श्लोकार्धानुक्रमणिका

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